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WOMEN IN THE WORKPLACE

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September 1988

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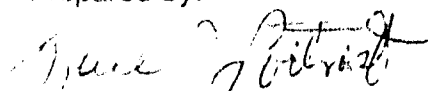
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I. INTRODUCTION

The number of women in the work force is increasing. Studies involving working women are relatively few though increasing. There is a need for such studies as there are physiological and anatomical differences between men and women which may have importance when disease and injury are considered. In the absence of firm data, decisions must still be made regarding the health and safety of women at work. This is not a strange or unusual position for physicians to find themselves in. Virtually all medicine is practiced as an art, ahead of the available science.

This report is an attempt to present basic information regarding the physiologic differences between men and women as well as differences in susceptibility to adverse health outcomes related to work place exposures. Understanding these differences will aid the health professional in setting appropriate work practice/exposure guidelines for fertile, pregnant or breast feeding workers and in most instances there will be no differential effect. In some cases there will be an effect but it will be of no consequence. However, in a few cases there will be important sex specific differences which will make an informed decision regarding exposure/work practice restrictions critical. There is a need for balance. The woman's right to work should not be denied merely because of uneasiness about her working in a certain situation. Every reasonable effort must be made to determine the facts and base our decisions on them.

II. MALE-FEMALE DIFFERENCES AND DIFFERENTIAL ENVIRONMENTAL RESPONSE

A. LUNG

The lung-surface/body-volume ratio is larger in men than in women. A potential effect of this fact is that men will absorb larger doses of substances inhaled over shorter time periods than similarly exposed women. Their blood levels will rise more rapidly than a woman's but also will fall more rapidly when the substance is removed from the environment. In most work environments this will not matter, as the exposure levels are so small in most cases that this ratio is irrelevant.

B. BODY FAT COMPOSITION

Normal Body fat content in women is proportionally larger than that in men. The storage volume for fat soluble substances is therefore greater. Problems may arise with fat mobilization for milk formation.

C. HORMONES

Male hormones are anabolic. Female hormones tend to inhibit anabolism. This leads to differences in oxidative metabolism. As a result, those carcinogens which require oxidation for activation are more likely to cause cancer in men. The direct acting carcinogens are more active in women because they remain in their original state for longer periods of time. The same holds true for any other toxin where a difference exists in toxicity between the oxidized and unoxidized forms.

D. SEX-SPECIFIC ORGANS

The breast is a very fatty organ and quite metabolically active. The difference in breast cancer rates between men and women is obvious to all. The potential for fat soluble carcinogens to cause differential rates of breast cancer is equally obvious.

Some chemicals are known to have estrogen-like effects. DDT is a case in point and will be discussed later.

E. STRUCTURAL DIFFERENCES

The wider female pelvis throws the hip further to the side than in the male. This decreases the lateral angle between the femur and the tibia. This smaller angle enhances the likelihood of patella and knee dislocation. The female spine is longer for size than is the male spine and, in combination with the ligamentous relaxation and the change in weight distribution caused by pregnancy, increases the probability of L5-S1 disk herniation.

F. ENERGY EXPENDITURE

The male/female maximal attainable energy expenditure ratio is 1.42/1. This should matter only in those jobs where the required output is unpredictable in time and circumstance. In a job such as firefighter or police work, this may become important. Some of the female characteristics responsible for the differential in maximal energy expenditure are as follows:

- a. vital capacity 11% less.
- b. hemoglobin 20% less.
- c. larger skin area to circulating volume.
- d. smaller body water/body weight ratio.
- e. larger body fat content.

Other effects of these factors are a decreased heat tolerance and an increased cold tolerance. The decrease in heat tolerance is due to the fact that more of the total circulating volume in a woman must be shunted to the skin when cooling is required. The increased body fat serves as an insulator in both heat and cold. It will slow heat loss in both circumstances. Some investigators have found there to be little practical difference; however, NIOSH has done a very complete study of the issue and has recommended different standards for men and women for heat. In general women will endure as long as men. They will put out a lower level of energy in a given unit of time but because of this they may be able to perform for a longer period.

G. MENSTRUAL CYCLE

Among the more emotional issues is the menstrual cycle. This is not surprising given the central position it has occupied in our mythology. In times when people were less technically sophisticated the mystery of birth was central to their religions. It was thought that

the menstrual blood was the principle of life and creation. Thus female gods were paramount. As religions became male oriented, things like witches and menstrual flow became bad things because they represented the Goddess, the competitor for supremacy. As part of the reformation to male dominated religions it was necessary that what had been sacred formerly must now be profane. The time of the menstrual flow had been considered holy. It was "the moon time," the monthly visitation of the goddess. Now it became a time of seclusion, a time when it was unacceptable to be in the temple. Being moonstruck, formerly a sign of the Goddess' favor, became associated with madness. Things have not changed much in our time. The premenstrual syndrome has been used as a defense for child abuse, murder and mayhem. Women's mental capacity is still questioned at the time of menses. Lawyers and myths notwithstanding, the effect of menses on work capacity is negligible. The most important factor is the degree of dysmenorrhea. It determines the ability to concentrate, and is the only consistently measurable factor affecting performance. With the average woman there is a 10% decrease in endurance and work capacity during her period. This is not significant and is considerably less impairment than is experienced by the person who has a slight hangover. Some women who suffer from Major Affective Disorder do get into trouble during the premenstrual phase of their cycle. This is a relatively rare problem and easily treated in appropriate psychiatric channels.

H. STRENGTH

At age 20 the lifting strength of the average woman is 65% that of the average man. The push-pull strength is 75% that of a man. This general relationship will persist in the face of equal training. At age 55 both the lifting and push-pull strength of women fall to 55% that of equally aged, equally trained men. Again, this is a fact to be kept in mind, not a determiner of employment. Lifting injuries are in direct proportion to the maximum lift required by the job and its relationship to the maximum lift the person is capable of making. Where any individual is concerned, the latter fact is more important.

Strength testing as it is accomplished in the USAF is of no value for determining the ability to accomplish a job. The system is a single parameter attempt to answer a complex problem. To accomplish appropriate testing is not that difficult. When the job description requires the ability to lift 25 pounds it is important to know in what position and how often the task must be done. Twenty pounds held at arms length is very different from 20 pounds at the chest. Please keep this in mind when writing pregnancy profiles. In general, no one should regularly lift more than the equivalent of 25 pounds held at the chest. This exerts a force of 300 lb-cm at the base of the spine. If held at arms length the force becomes 1500 lb-cm. Five pounds at arms length exerts the same force as 25 held at the chest. Pregnancy introduces the added factor that the pelvic ligaments become slack as pregnancy progresses. This is especially true in the last two months of pregnancy. Women who have had one pregnancy are at a significantly increased risk of L5-S1 disk herniation.

I. LACTATION

Another potential female specific problem is lactation. There are concerns that the exposure of the mother to chemicals at work will affect the child by way of the milk. There are a number of parameters which will allow you to make a judgment in this matter. Give consideration to the following factors:



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- a. What are the exposure levels at work?
- b. What are the toxic characteristics of the substances?
- c. Attempt to determine the following characteristics of the chemicals concerned:
 - (1) Fat solubility
 - (2) Molecular weight
 - (3) Serum half-life

With the above information it is possible to make an educated judgment regarding the danger of toxicity to the child.

With regard to exposure levels at work, with organic chemicals, the danger to the infant is probably never greater than 25% of the risk to the mother. No harm to the infant has ever been demonstrated if the maternal exposure is kept at or below the TLV. The same cannot be said of metals. Women working with metals or metal vapors should either avoid breast feeding or have their milk tested for metals before starting to breast feed.

The fat solubility of a substance is measured by a ratio called the octanol/water (OW) partition coefficient. This is expressed as the log of the ratio of the solubility of a substance in octanol to its solubility in water. Thus a substance with an OW of zero would be equally soluble in fat and water. Those with higher numbers would be more soluble in fat. Those substances which have a molecular weight over 200 or are highly charged, will pass the lipid membrane with difficulty.

If a substance has a short serum half-life, then it is unlikely to accumulate to any extent in breast milk.

Because of the high blood flow to milk formation ratio, 400/1, even substances which are at low levels in the blood may become concentrated in the milk. (When an agent has similarity to a biological agent, greater caution must be exercised as in many cases the foreign agent may receive the same priority in handling that is accorded the biological agent.)

J. PREGNANCY

There is a general increase in metabolic rate during pregnancy. This leads to a decrease in susceptibility to direct acting toxins and an increase in susceptibility to indirect acting toxins. Because of a general tendency toward physiological compensation, the pregnant woman can generally maintain the same level of work that she was accustomed to prior to pregnancy. In the last six to eight weeks a decreased work capacity should be expected. There is a general loosening of the pelvic ligaments during pregnancy. Because of this and the change in posture due to the change in weight distribution there is increased susceptibility to low back injury in the latter part of pregnancy and in the first few months following delivery. The risk of prolapse is also increased in the time following delivery. Several months may be required for return to normal.

K. NUTRITION DURING DEVELOPMENT

Early nutrition is taken from decidual cell secretions. By the twelfth week nutrition is entirely by way of the placenta. Some substances accumulate in the placenta during early pregnancy. They are later used to supplement diffusion and active transport in supplying nutrients during rapid growth when the transport systems are inadequate to the task. Calcium is one such substance. Agents similar to calcium, such as lead, will also be stored and may have a delayed effect on the infant when they become available in quantity later in development.

The rules for placental transfer are the same as for transfer across the lipid membrane of the breast and lipid membranes in general. They are:

- a. The majority of transfer is passive.
- b. Fat soluble substances pass more easily than water soluble.
- c. Charged molecules pass with greater difficulty than in noncharged.
- d. Higher weight substances pass with greater difficulty than lighter substances. For practical purposes, substances with a m.w. of 1,000 or greater do not pass the placental membrane.

L. BIRTH DEFECTS

A teratogen is a substance which causes a developmental defect in a child without causing a toxic effect in the mother. At present it is believed that 20% of defects are caused by genetics and 10% by the environment. The rest are of unknown cause. The timing of the insult has much to do with the location and form of the defect. Interference with reproduction at the time of gametogenesis or pre-implantation is most likely to result in miscarriage. Interference at the time of embryogenesis results in gross morphological defects. The most sensitive time is between day 15 and day 40. Interferences during fetal development may result in abnormalities of the genital tract or in histogenic or cell-physiologic abnormalities.

There is much concern that the 70% of malformations which are of unknown origin may be of environmental origin. There is no justification for this statement. The over-all rate of malformations has not increased with the advent of the rise in industrial activity. Individual, categorical rates vary. Some have gone up while others have gone down. These fluctuations are within the range of the first standard deviation and do not represent changes.

M. RADIATION

1. Ionizing Radiation

The standards for protection for ionizing radiation are set by the National Council on Radiation Protection. The basic standard is the lowest level practicable. This is the so-called ALARA level (as low as reasonably achievable). This does not mean zero exposure. It

assumes that there is no threshold for effect. For a radiation worker the allowable dose is 5 rem per year. For the developing child the allowable level is 0.5 rem in nine months. Theoretically, no fertile woman should be exposed above this level because of the problem with early detection of pregnancy. This is not allowed under current anti-discrimination guidelines. The 0.5 rem guideline may be considered when a woman is actively attempting to become pregnant. Current Air Force policy in determining if a job is permissible for a woman who is pregnant is to judge whether or not it is likely that the fetus will receive a dose of 0.5 rem during the nine months. If it is likely, then her job must be changed. For example, it is unlikely that an x-ray technician will receive a dose amounting to an excessive fetal exposure in the nine month period. A female who works with liquid isotopes might be considered more at risk for such an exposure because of the potential for spilling these substances. The dose in such a spill might be excessive.

The hospital x-ray department is the major contributor to worker radiation exposure. Industrial x-ray technician exposure is generally half that of the hospital technician. Keep this in mind when the question of females working in NDI is raised. They are less likely to have an excessive exposure than is the hospital technician.

Radiation effects for acute doses up to 50 rem in utero may be summarized as follows:

- a. Pre-implantation radiation will most likely result in failure to implant.
 - b. Up to 20 weeks the most likely effect is *microcephaly*.
 - c. After 20 weeks minor changes of the skin and blood forming organs are seen.
2. Nonionizing radiation

In this section we will consider:

- a. Ultraviolet
- b. Visible light
- c. Infrared
- d. Radio frequency radiation

We can dispense with ultraviolet, visible light, and infrared for purposes of this discussion by saying there are no sex-specific effects known. There are no sex-specific effects for radio frequency radiation either, but because of concerns regarding microwave and low frequency in-utero effects, we will spend some time on them.

No robust effect of radio frequency radiation, beyond that caused by heating, has been demonstrated. Much has been written about nonthermal effects but none have been shown to exist. There has been a recent surge of interest in the effects of magnetic fields at

high frequencies as well as low because of alleged effects on cell division. These effects have not been duplicated as of this writing. We will continue to hear about these concerns, no doubt, but at least for now, no problem has been demonstrated at levels which would not also represent a danger to the mother.

N. NOISE AND VIBRATION

There are no sex-specific effects of sound and vibration. Again the concerns relate mainly to pregnancy. Sound couples poorly with the body. Any effect it has is related to hearing. The uterus is a fairly effective sound attenuator. Its ability to attenuate sound varies from 39 decibels at 500 Hz to 50 decibels at 3000 Hz. The sound level in the uterus from physiological processes is about 85 decibels.

Vibration is another matter. When contact with vibrating surfaces is direct, coupling is very effective. Vibration in the range of 5 to 10 Hz is resonant with the human body and can be very damaging. If of sufficient intensity it can cause the bowel and bladder to empty and may produce hematuria. It may also result in abortion. Such levels may be found in jet fighters if they are run up to 90% power while being restrained. There is no reason to run the power to this level while checking them out. It is done occasionally and should be a consideration in female crew chiefs when pregnant. The presence of hematuria in flight line personnel may be a sign of this unnecessary practice.

O. METAL: There are some sex-specific toxic effects known for certain metals.

1. LEAD

Chronic dosing with lead suppresses ovarian function. It is also a cause of embryo loss. Embryo loss results from toxic effects on the mother rather than as a result of direct toxic effects on the embryo. Maternal blood lead levels above 30 $\mu\text{g}\%$ are a cause for concern.

2. MERCURY (Hg)

This is a very toxic metal. Poisoning is usually worst in the kidney and central nervous system (CNS). The inorganic mercurials are more toxic to the kidney than are the organics, but the organics are much more toxic to the CNS than the inorganics. The mode of toxicity appears to be the same in both cases, i.e., the inhibition of intracellular enzymes by mercury. The water-soluble salts are ionized and thus find more difficulty in crossing the blood-brain barrier and tend to accumulate in the kidney and the placenta. In the low molecular weight, organic forms are much more lipid soluble and therefore find their way into the CNS much more rapidly. In the case of the metal itself, the vapor is not oxidized in the blood for about two and one-half transits of the vascular system. This means that as an uncharged particle it can readily pass the lipid membrane and so gain ready access to the brain. Methyl-mercury is a particularly toxic substance because of its small size and ready fat solubility. The fetotoxic dose is very close to the TLV. No pregnant woman or one planning to become pregnant should be allowed to work with it. Fetal sensitivity is ascribable to a more permeable blood-brain barrier and a still rapidly dividing CNS.

3. COPPER (Cu)

Copper has sex-specific effects in the deficiency state but has no known sex-specific toxic effect when in excess. In mammals fed a diet deficient in copper, the males suffer a marked increase in heart disease while the females do not. The reasons for this are unclear at the moment. The females become somnolent and withdrawn while the male does not. The work has been replicated in human females and the same effect found.

4. BERYLLIUM (Be)

This metal is found in the dental laboratory and on the flight line. Efforts have been made to limit its use in aircraft, but it is still used in some applications. It is a strong, light metal with great durability. As such it has found use in fillings for teeth and in other applications where the metal can be expected to be subject to repeated forceful pressures. It has the additional qualities of being non-sparking and ductile and when used in alloy with copper is both conducting and non-sparking. These qualities have led to its use in conductors for the doors of Faraday cages and as metal strike plates in the wheel wells of some aircraft. It is frequently stated in the literature that the problem from this metal is the result of the metal oxide and that the Be-Cu alloy is free of problems. While the alloy is less toxic, adverse reactions attributable to Be are seen as the result of contact with the alloy. For instance, Be in a cut can cause a chronic granulation formation which will not heal until the Be is removed from the cut. Lacerations caused by the Be-Cu tabs on Faraday cages have been known to cause this same reaction. Formerly the backing plate for the brakes on the C-5 aircraft was a Be alloy. These have been in process of replacement and may be all gone by now.

The metal is highly chemically reactive and was used in rocket fuels because of the great increase in specific impulse it gives. It is being re-introduced as an element in fuels intended for use outside the atmosphere. The oxides formed at the high temperatures of rocket exhaust are said to be much less of a problem than the low temperature oxides formed by this metal.

In terms of women, there are no true sex-specific effects; however, there are some problems more likely to arise in women than men because of pregnancy. If a woman is exposed to Be and develops acute Be toxicity, she is at risk for re-activation of the disease if she becomes pregnant. Time to last exposure seems to be irrelevant. This presents as a rapidly developing, fulminating disease which is difficult to diagnose and which has a 60% fatality rate. This syndrome has been found to develop as the result of any acute stress in either sex. Operations, serious trauma, and sometimes simply growing older seem to be sufficient causes. As a less rapid disease, it is indistinguishable from saroid.

5. CADMIUM (Cd)

Women exposed to this metal tend to accumulate significantly more of it in their kidneys than men. This causes an increase in renal disease over men exposed at the same level. Cadmium also accumulates in the placenta just as lead does because of similarity to calcium in the way it is handled metabolically. Be, Hg, and Cd are all found in dental laboratories.

P. CHEMICALS

1. ORGANIC SOLVENTS

Because of the factors discussed earlier, namely, increased fat levels and anabolic inhibition caused by female hormones, women will be more prone to suffer the ill effects of solvent exposure than men. The types of problems seen are exemplified by the effect alcohol has on women. Women alcoholics run into problems much more rapidly than men. Muscle wasting, peripheral neuropathy, behavioral changes, weight loss and liver damage all occur much faster. The same may hold true for other solvents. In addition some solvents have idiosyncratic effects. Benzene used to be used as a solvent, and its bone marrow effects are well known. This is not a common solvent effect.

Not many substances are going to have adverse effects at the typical exposure levels found in industry. Alcohol has obvious fetal effects and it may be expected that other solvents may have similar effects. However, if you stop to consider the amount of alcohol that people are exposed to when they drink and compare it to industrial exposures to solvents, you will see why there should be more concern about women drinking alcohol. It takes four ounces of alcohol a day to cause the fetal alcohol syndrome. This is 96,000 mg of alcohol. The typical mixed drink contains 12,000 mg of alcohol. Exposure to an industrial solvent at 50 mg/m³ would take a long time to equal that amount. The average person breaths about 10 m³ per day at work. This means they breath about 500 mg of the solvent or 0.5% of the amount of alcohol necessary to create fetal damage.

2. HALOGENATED ALIPHATIC PESTICIDES

These have effects similar to halogenated solvents. Their effect on the CNS is poorly understood and except for the problems possible with breast feeding and greater female absorption of these kinds of compounds, no sex-specific effects are known

3. CYCLIC CHLORINATED HYDROCARBON PESTICIDES

The only pesticide with a specific effect on females that I was able to find was DDT. O,P,DDT has effects similar to DES.

4. CARBON MONOXIDE

Carbon monoxide can cause fetal death in an asymptomatic woman. The shift in the oxyhemoglobin dissociation curve is responsible. The smoking of cigarettes can cause a significant effect. Fetal death, low birth weight, and prematurity are all more common in smoking mothers. A smoking mother may well place her child at risk by smoking in an environment where carbon monoxide is already present.

Q. THE HOSPITAL

Don't forget to look close to home. Most workers in hospitals are women. Hospital laboratories are generally poorly designed. Exhaust hoods at ceiling level are common and totally useless. They will in fact aggravate the problem. Vapors are drawn right through the

breathing zone. Operating rooms are a potential source of many, very fat soluble substances used as anesthetics. Most ORs have more than adequate ventilation systems. This is fortunate because most anesthesia machines leak like sieves. No real attempt to engineer tight induction systems has been made. Hospitals have had very poor records of health and safety. Only in recent times have they begun to come under scrutiny and develop procedures for control of dangerous substances. Most medical professionals believe they are knowledgeable in the areas of concern relating to occupation, but in fact they are not. This combination of circumstances makes the hospital a difficult place to enforce safety and health regulations. The same factors hold true in research labs. Don't neglect these areas if you have them on the base.

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